Defending Our Aging Fleets: Defining the Impacts of Aging Aircraft Sustainment on Warfighting Capability

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1.0 INTRODUCTION

Top Air Force (AF) leaders are concerned about the impact that aging of the United States Air Force (USAF) aircraft inventory has on operational readiness and mission capability – an issue that will not easily be fixed.

General Moseley, Chief of Staff of the Air Force (CSAF) recently said, "The USAF is concerned primarily with three objectives: 1) Fighting and winning GWOT, 2) taking care of AF personnel, and 3) recapitalization and modernization of the AF's aging fleet." But he knows that the third objective will not be finished anytime soon especially with the tanker inventory. He stated, "We will keep them (KC-135R) around for a while because the (KC-X tanker replacement) won't deliver fast enough to divest ourselves of those airplanes in the short term." He also knows the effect. The CSAF admitted, "Maintaining the older aircraft it would like to retire is an issue." [1]

While the senior AF leadership recognizes the need to replace and/or upgrade our aging fleets and that it will not be accomplished soon, they also confirmed the need to effectively manage the aging fleets until they can be replaced and/or upgraded.

In October 2005, then Acting Secretary of the Air Force (SECAF) Pete Geren said, "The process of recapitalization and modernization can never be finished. Even if we buy everything we are planning to buy over the next 5 years, we will still have the oldest (inventory) in the history of the Air Force. If you fast forward 20 years from now, the CSAF and the SECAF will still be working that problem." And, "There will never be a time where I believe we can be complacent about the need for investment in new technology." CSAF General Moseley echoed Mr. Geren's comments, "With an aging inventory that begins to cost you more money, you have less operational readiness and less opportunity to deploy the force." [2]

The AF has a significant number of old aircraft. As of FY06, 20% of the AF fleet has an average age of 40 years or more. The KC-135s have a fleet average age of over 45 years, the B-52s have an average age of nearly 45 years, and the C-130Es have an average age of over 41 years. It will take years to replace these numerous aircraft. General Moseley has admitted that even with a tanker replacement program, he expected the last KC-135R will still be around for an additional 30-plus years as the new tankers are delivered to squadron service. [3]

Therefore, a long term strategy for enhancing the AF fleet's warfighting capability must include a long-term aircraft sustainment plan because modernization and recapitalization cannot happen overnight. In addition, to ensure these aircraft will be in flyable condition until the last aircraft are replaced, sustainment must be a funding priority. To make this prioritization a reality and to justify improved funding, AF aircraft maintainers must better communicate the importance of sustainment. To be successful in this endeavor, the AF aircraft maintenance community needs to equate sustainment to warfighting capability. Note: For the purposes of this paper, sustainment is defined as the activities involved in maintaining an aircraft in good working order with the goal of ensuring its availability to meet its mission (versus enhancing its capability with emerging technical requirements).

To that end, this paper will make a connection between mission capability (MC) rates (the hours a fleet is available to perform missions versus the hours a fleet is possessed by a flying unit) and the flying unit's warfighting capability using the USAF Mobility Air Force's (MAF) aircraft as an example. One of the MAF's warfighting capabilities is airlift that rapidly transports military personnel and equipment to operating locations throughout the world. [4] Two approaches of this connection between MC rates and the MAF's airlift capability will be presented:

1) A model will be developed to a) calculate the historic mobility airlift capability (MAC) of the USAF's Air Mobility Command (AMC), measured in million-ton-miles per day (MTM/D), from fiscal year (FY) 1991 to 2006, and b) forecast the MAC from FY07 to FY16. This model will be a function of the airlift aircrafts' MC rates and the number of unit-possessed aircraft for any given FY. AMC's MAC is currently achieved by the C-5, KC-10, and C-17 fleets. Therefore, to fully accomplish their mission, each aircraft must operate at certain MC rate goals. If the MC rates fall below these goals, AMC may be unable to meet its required capability.

2) Analyses will be given to establish reasons why the MAC is not higher. This paper will introduce these reasons in terms of a) specific high maintenance drivers of non-mission capability (NMC) rates – the converse to MC rates (where it will be shown that, for the C-5 aircraft, higher NMC rates are caused by increasing rates in aircraft downtime due to scheduled and unscheduled maintenance and supply problems); and, b) general influences impacting the MAC per aircraft, total MAC, and MC rates.

Sustainment, then, serves to address these NMC problems. Reducing the severity of high NMC rate drivers directly results in improvements to MC rates and consequently increases the fleet's warfighting capability (i.e., more cargo delivery). Note: For the purpose of discussion in this paper, warfighting capability refers to the weapon systems' overall mission type in fighting a war (cargo delivery, fuel delivery, bombs on target, threats detected, etc.). The actual wartime requirement will not be presented.

2.0 BACKGROUND

This section describes other work related to the area of MC rate forecasting and simulations:

1) A straightforward method to forecast MC rates was cooperatively developed by the Institute for Defense Analysis and the Studies and Analysis Flight at Headquarters (HQ) AMC. This approach was derived from a need to estimate the MC rate of different modernization proposals for the C-5. The result was a simulation model that considered the contributions of individual aircraft subsystems that are being upgraded to overcome the C-5's aggravating reliability problems. The model is based on component failure distributions and actions and on component repair time distributions and actions. [5]

2) A discrete approach to simulate military aircraft maintenance and availability was developed by the Systems Analysis Laboratory at the Helsinki University of Technology. This model was constructed for use on the Bae Hawk Mk51 aircraft and describes the flight policy and maintenance, failure, and

repair processes. It aims to shorten maintenance turnaround times and perform what-if scenarios for investigating ways to improve MC rates. [6]

3) An extensive analysis of MC rate forecasting was completed through a joint effort between the Maintenance Plans and Programs Branch of the Air Force Logistics Management Agency (AFLMA) and the Air Force Institute of Technology (AFIT):

   - They first evaluated the AF's Funding/Availability Multi-Method Allocator for Spares (FAMMAS) tool, a parametric model that forecasts MC rates by aircraft type based on funding projections of aircraft readiness spares and other associated planning factors. This effort discovered the FAMMAS model did not incorporate or explain the key logistics and operations drivers that influence MC rates. The researchers concluded that this limited its effectiveness as a management and decision-making tool.

   - Second, the effort sought to enhance the forecasting ability of MC rates by recommending the integration of significant factors besides funding. This was accomplished through the examination of over 600 variables from aircraft reliability, maintainability, operations, and personnel areas, and 10 years of data. The research acknowledged that MC rates are linked to logistics type factors including logistics operations, reliability and maintainability (R&M), and personnel, and operations type factors including aircraft operations, funding, and environment.

   - The result was the development of two versions of an enhanced forecasting model that is a function of sorties, flying hours, average aircraft inventory, number of maintenance personnel assigned, and the interaction of the logistics and operations factors. The first version serves as a point estimator of an MC rate at a specific time in the future while the second version serves as a long-range planning model. [7]

3.0 MOBILITY AIRLIFT CAPABILITY MODEL

3.1 Basis of Model

The basis of this Mobility Airlift Capability Model comes from the FY00 MAC data for the C-5, KC-10, C-17, and C-141 aircraft presented in GAO-01-495R (see Figure 1). [8] GAO-01-495R updated the information provided in GAO/NSIAD-00-135 [9] which was written to assess the adequacy of U.S. mobility forces in transporting military personnel, equipment, and supplies necessary to execute the National Military Strategy.

Aircraft	FY00 Mobility Airlift Capability (MTM/D)
C-5	9.17
KC-10	3.01
C-17	5.09
C-141	3.71
Total Military[a]	20.98
CRAF[b]	20.50
Total Capability	41.48

[a]based on FY00 average MC rates

[b]Civil Reserve Air Fleet. Both the 1995 Mobility Requirements Study Bottom Up Review Update and the Mobility Requirements Study 2005 cite that 20.5 MTM/D will be provided by the civilian fleet

Figure 1: Mobility Airlift Capability by Aircraft.

From the MAC data provided by GAO-01-495R, one can determine the airlift capacity per aircraft (MAC/aircraft). In this case, because the MAC was based on the mission capability rate, the MAC per aircraft is really MAC per MC aircraft. Therefore, to determine the historical MAC (FY06 and before) one only needs to obtain the number of MC aircraft for each FY and multiply by the MAC/aircraft. To determine the forecasted MAC (FY07 and beyond), one needs to develop a methodology to predict the future number of MC aircraft by FY and multiply by the MAC/aircraft. See equation 1.

$$MAC = (MAC/MC\ Aircraft) \times (\#\ Possessed\ Aircraft) \times (MC\ Rate)$$

Equation 1. Mobility Airlift Capability

The remainder of this section will present historical data and methodologies used to derive the historical and forecasted MAC.

3.2 MAC Model Methodology

The MAC for any FY is essentially the MAC per MC aircraft (derived from the FY00 data in GAO-01-495R) multiplied by the number of MC aircraft for that FY. The methodology will consist of determining the number of annual possessed aircraft, the annual MC rates, and the MAC per MC aircraft (refer to Figure 2 for a schematic view of the process).

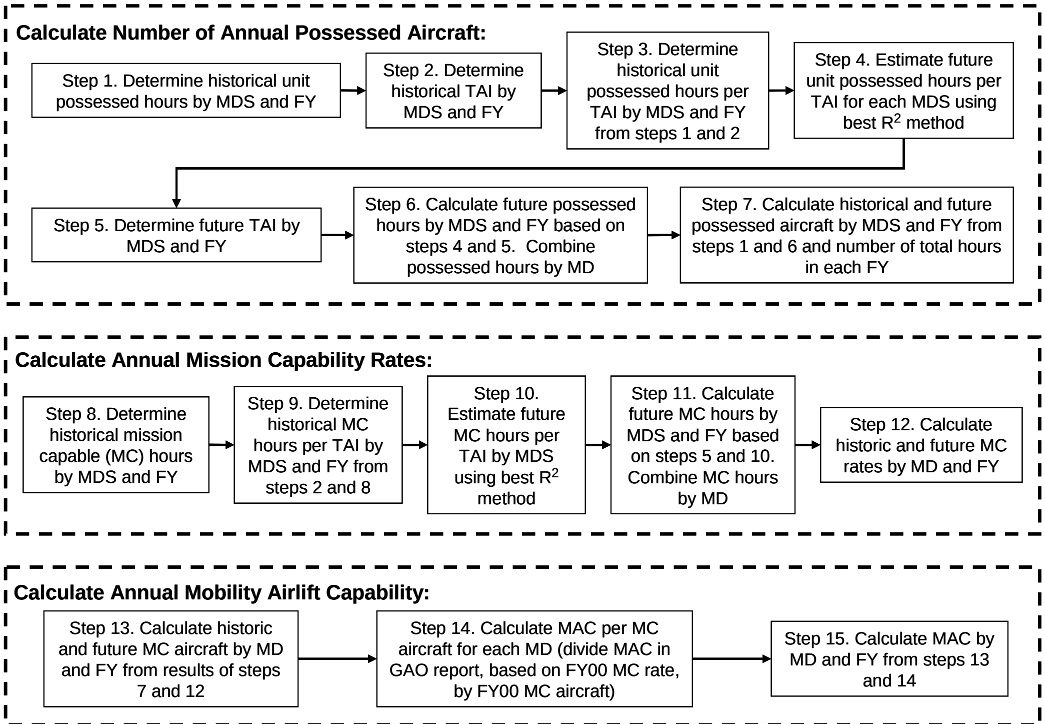

Figure 2: Schematic View of Mobility Airlift Capability Model Methodology.

As with any methodology, the assumptions must be explained so as to provide the boundaries (and limits) of the methodology.

3.2.1 Assumptions

1) The MAC per MC aircraft for each weapon system stemming from the FY00 data in GAO-01-495R is a constant over the entire analysis period. The author acknowledges that there have been a variety of modifications on each weapon system prior to FY00 (thus possibly overstating the capability), between FY01 and present day (thus understating the capability), and planned for each weapon system from now through the FYDP and beyond (thus understating the capability even more). Since the intent of this paper is focused on building a methodology to quickly produce results that closely (versus exactly) represent the real world (same order of magnitude), using a constant MAC per aircraft was not seen as a deterrent to the development of the concept of making a connection between MC rates and the flying unit's warfighting capability.

2) The forecasted metrics by mission design (MD) are the forecasted metrics by mission design series (MDS) added together by MD. This was done because a critical piece of the formula, the MAC data, was furnished by GAO-01-495R according to MD (e.g., C-141, C-5, etc.). So, the historical data and forecast calculations were first derived by MDS (e.g., C-141B, C-141C, C-5A, C-5B, C-5C, etc.) and then consolidated by the composite MD before it could be matched with the GAO MAC data.

3) The C-5 is undergoing major modifications (Avionics Modernization Program and Reliability Enhancement and Re-engining Program) to improve fleet logistics departure reliability, performance, and

availability {MC rates}).[10] The modified C-5s will be re-designated as C-5Ms. Since there is no historical data available yet for the C-5M, the conversion to C-5M will not alter the total aircraft inventory (TAI), and, other than a targeted MC rate goal of 75%, no official AF-certified C-5M forecast calculations for MC rates have been obtained. Therefore, only data from the C-5A, C-5B, and C-5C will be used in the composite C-5 forecast. Note: The C-5 MC rate simulation model mentioned in this paper's Background section, paragraph 1, was only a study – the author could not ascertain if this was an official C-5M forecast by HQ AMC.

4) Because the number of TAI is more of a known quantity and because the unit-possessed hours and MC hours are related to the number of aircraft in the inventory, estimating future trends was first based on a historical per TAI basis. Then, to calculate the actual predicted value, the "per TAI" forecasted number was multiplied by the forecasted TAI for each respective FY.

5) According to GAO-01-495R, both the 1995 Mobility Requirements Study Bottom-Up Review Update and the Mobility Requirements Study 2005 cite the Civil Reserve Air Fleet (CRAF) will provide a capability of 20.5 MTM/D. [11] Many aviation carriers participate in the CRAF program to make civilian passenger and cargo aircraft available for military missions during times of crisis or war. This program avoids the cost of maintaining military systems that duplicate capability readily available in the civil-sector.[12] The author assumes the CRAF's 20.5 MTM/D to be a constant.

6) The future MC rates were forecasted by estimating the future unit-possessed hours separately from the future MC hours (MC rate = MC hours / unit-possessed hours). This was accomplished because their respective behaviors are not 100% related (annual unit-possessed hours are based on TAI, depot-possessed hours, and unit-possessed not-reported hours while annual MC hours are based on NMC hours in addition to unit-possessed hours). This will be discussed in more detail later in the paper.

3.2.2 Methodology

A step-by-step process is presented to explain how the historic MAC can be calculated and the future MAC can be predicted. Again, refer to Figure 2 for a schematic view of all the steps.

- Calculate the number of annual possessed aircraft:
  - ➢ Step 1 Determine the historical unit-possessed hours by MDS (C-141B, C-141C, C-17A, C-5A, C-5B, C-5C, and KC-10A) and FY.
  - ➢ Step 2 Determine the historical TAI by MDS and FY. The TAI was obtained as of the last day of each FY (30 Sep). It is noted that for non-constant TAIs, especially for the drawdown of the C-141B and C-141C, and the buildup of the C-17A, the TAI listed does not represent the average TAI throughout the FY. Since no easy method for determining the average TAI by FY was available through current USAF datamining techniques, the author believes this simple end-of-year accounting method shall suffice.
  - ➢ Step 3 Determine the historical unit-possessed hours per TAI by MDS and FY from Steps 1 and 2.
  - ➢ Step 4 Estimate the future unit-possessed hours per TAI for each MDS using the best R^2 method. See Figure 3 for the results. Note (a): For the sake of simplicity, estimating future trends was a process of plotting the historical data in Excel and utilizing its forecasting tool. The trend/regression type (linear, logarithmic, power, polynomial, and exponential) with the best R^2 was then chosen for each plot. Note (b): Granted there are a multitude of other statistical computations involved in selecting the most appropriate future trendline (including correlation,

variance, covariance, testing the results for mathematical reasonableness and confidence, etc.); however, the author did not want to add too much initial complexity to the MAC Model.

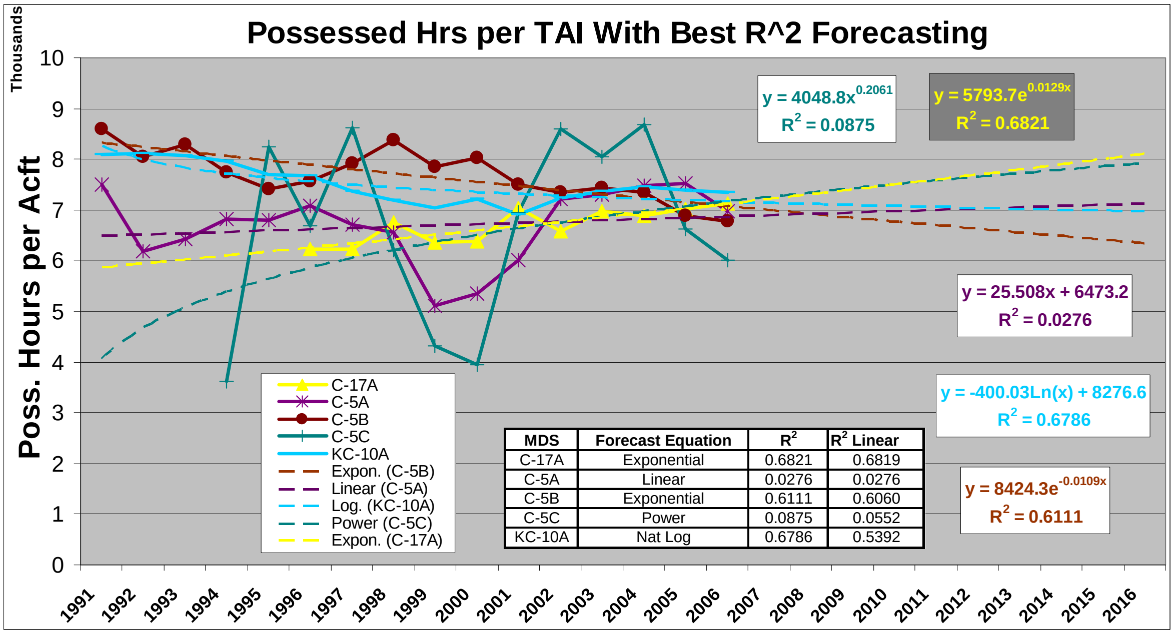

Figure 3: Possessed Hours per TAI with Best R^2 Forecasting.

- Step 5 Determine the future TAI by MDS and FY. Available resources include the President's Budget, Congressional Reports, DoD's Quadrennial Defense Review Report, Secretary of Defense's Annual Defense Report, AF Statistical Digest, etc. For the purposes of this study, a combination of the KC-10A's stable historical trend and current inventory level [13] was used to forecast its outyear TAI as 59 per year. The total outyear C-5 inventory (upgraded C-5A, C-5B, and C-5C) will be set at 112. [14] For the C-17A, since its final buy amount seems to remain somewhat unclear, the latest reliable total of 180 aircraft [15] will be used. This model can easily be updated when adjustments are made to the projected outyear TAI.
- Step 6 Calculate the future possessed hours by MDS and FY based on Steps 4 and 5. Combine the possessed hours by MD.
- Step 7 Calculate the historical and future possessed aircraft by MDS and FY. Do this by dividing the results from Steps 1 and 6 by the number of total hours in each FY (365 or 366 x 24, depending if leap year).

• Calculate the annual MC rates:

- Step 8 Determine the historical MC hours by MDS (C-141B, C-141C, C-17A, C-5A, C-5B, C-5C, KC-10A) and FY.
- Step 9 Determine the historical MC hours per TAI by MDS and FY from Steps 2 and 8.
- Step 10 Estimate the future MC hours per TAI by MDS using best R^2 method (see Figure 4 for the results and see notes (a) and (b) for Step 4 concerning the forecasting methodology used).

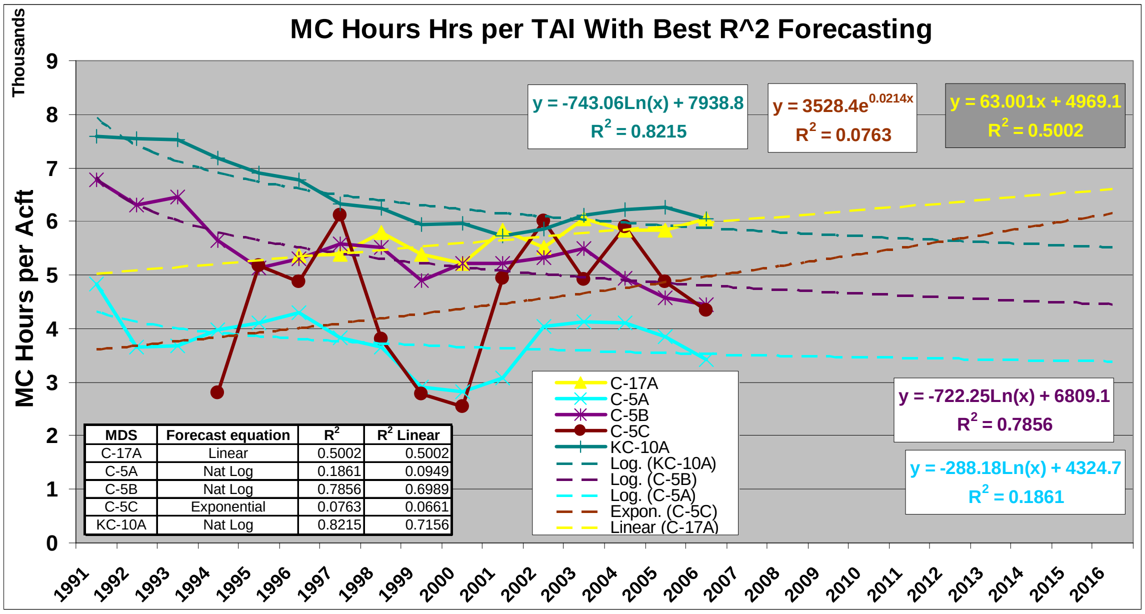

Figure 4: Mission Capable Hours per TAI with Best R^2 Forecasting.

- Step 11 Calculate the future MC hours by MDS and FY based on Steps 5 and 10. Combine the MC hours by MD.
- Step 12 Calculate the historic and future MC rates by MD and FY. Note: As can be seen in Figure 5, in every case the forecasted MC rates based on forecasted unit-possessed hours and forecasted MC hours yielded results that were more optimistic if not equal to the forecasts solely based on the rate alone. Note that while the MC rate for the C-5C is forecasted to experience a steady increase, it is only for two aircraft and thus will not have a serious impact on MAC.

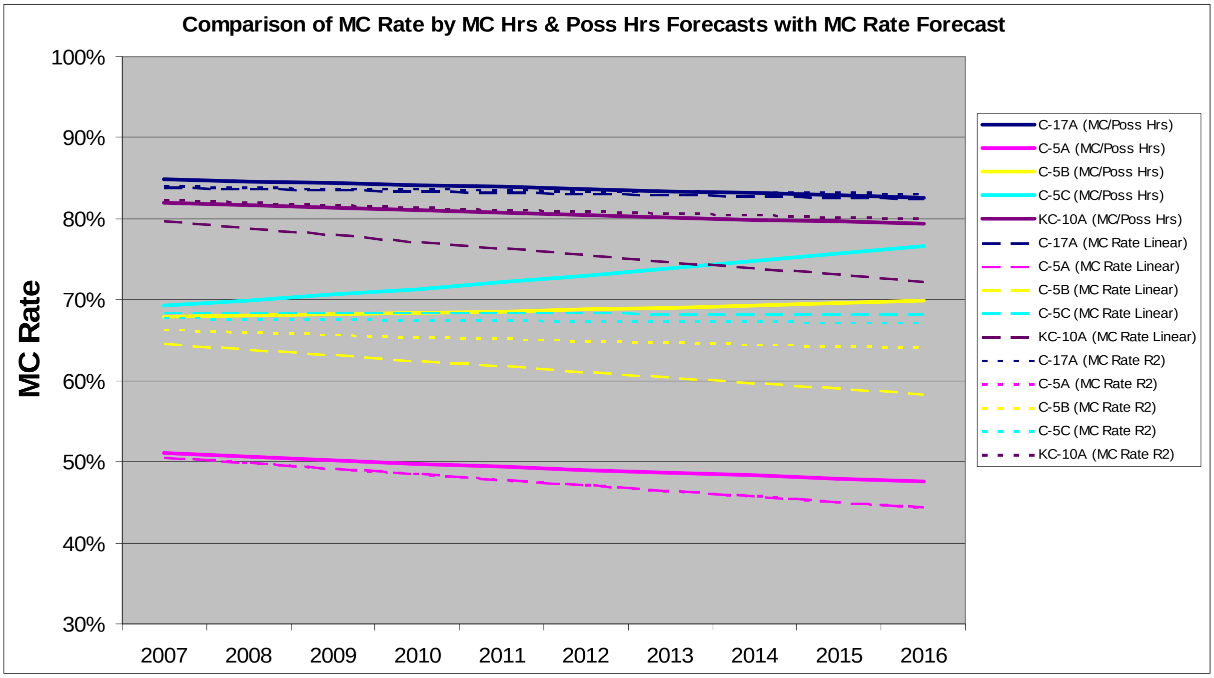

Figure 5: Comparison of Forecasted Mission Capability Rates.

- Calculate the annual MAC:
  - ➢ Step 13 Calculate the historic and future MC aircraft for each MD and FY by multiplying the results of Step 7 with the results of Step 12.
  - ➢ Step 14 Calculate the MAC per MC aircraft for each MD. Do this through the division of the MAC for each MD in the GAO-01-495R report (based on FY00 MC rate) by the FY00 MC aircraft for each MD.
  - ➢ Step 15 Calculate the MAC for each MD and FY by multiplying the results of Step 13 with the results of Step 14 (see Figures 6 (sand chart) and 7 (line chart) for the results).

3.3 MAC Model Results

3.3.1 Historical Results

From Figure 6, it appears that there were noticeable dips in the overall MAC in FY94, FY99-00, and FY05, and peaks in FY95-98 and FY03. In looking to the MAC by MD in Figure 7 to search for causes of these dips and peaks, one can see the FY94 dip was due to the C-141 and the FY99-00 and FY05 dips were due to the C-5. The FY95-98 peak was due to the short-term recovery of the C-141 in FY95 coupled with the introduction of the C-17. The FY03 peak was due to a sudden and short-term rise of the C-5 coupled with a slight surge in C-17.

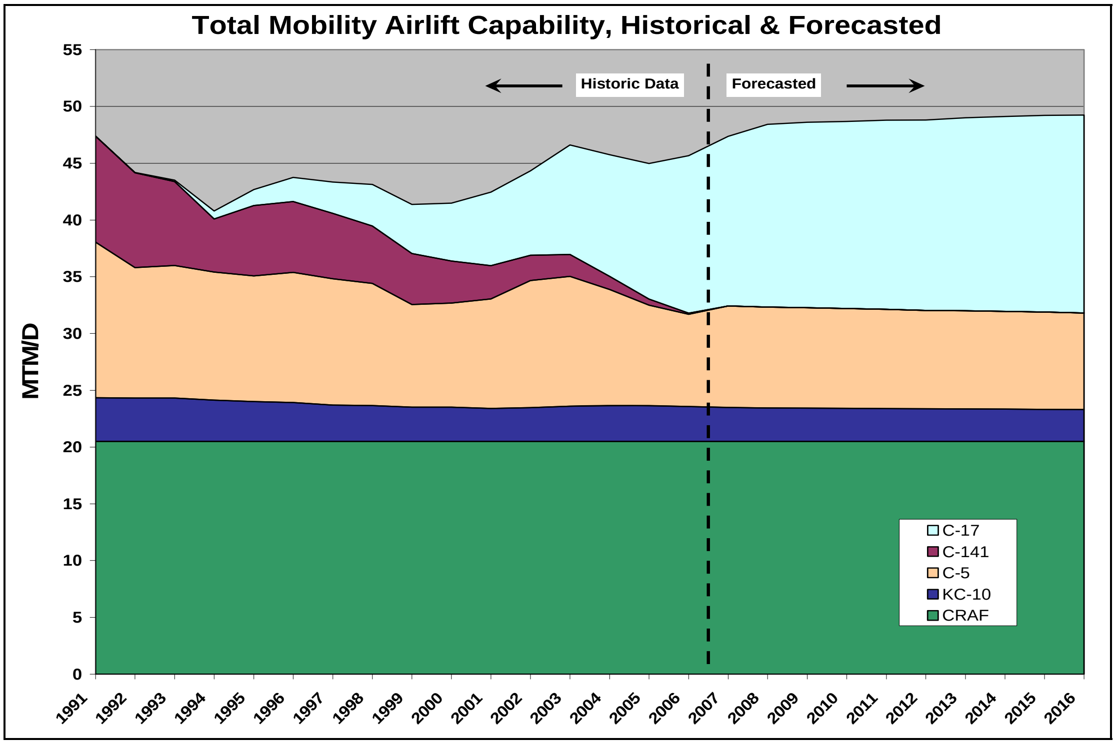

Figure 6: Historical and Forecasted Total Mobility Airlift Capability.

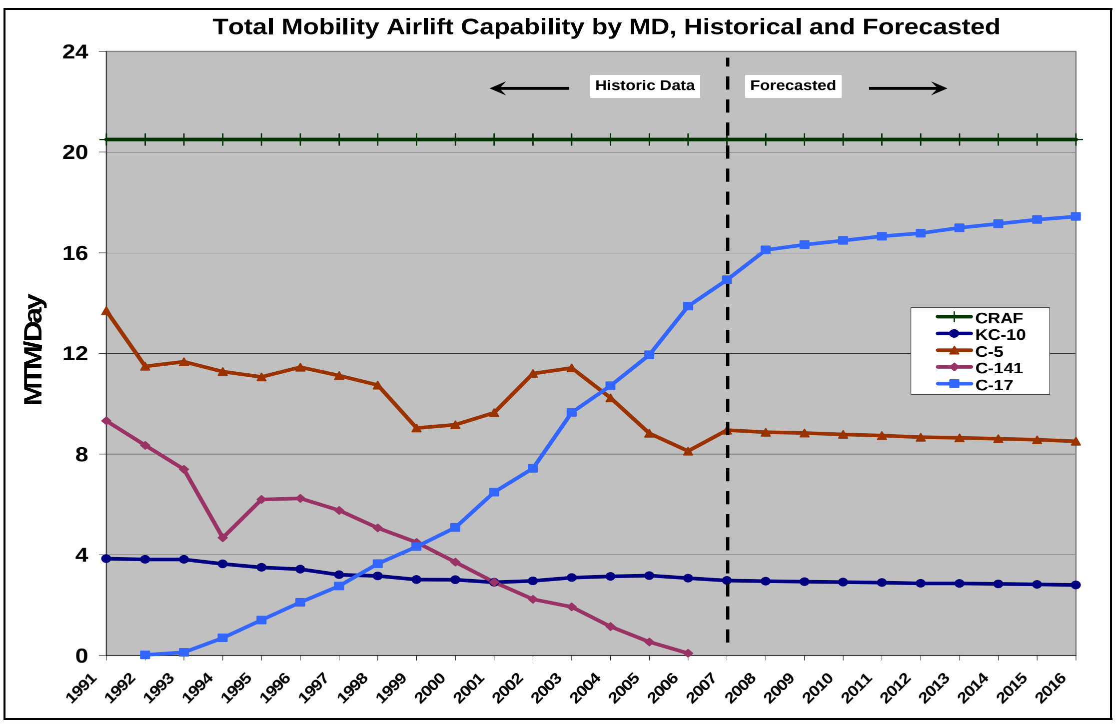

Figure 7: Historical and Forecasted Mobility Airlift Capability by Aircraft.

In exploring the MC historical rates in Figure 8 to search for causes for the peaks and dips, one can see how they influence the MAC. The C-141's dip in MAC is quite apparent from the dip in its MC rate. During FY95-98 timeframe, all four aircraft experienced a small peak in MC rate during one of the years and not all at the same time. This produced the relatively "flat" peak in the MAC over several years. Also, the FY03 peak in MAC matches with the FY03 peak in MC rates for the C-5, C-17, and C-141.

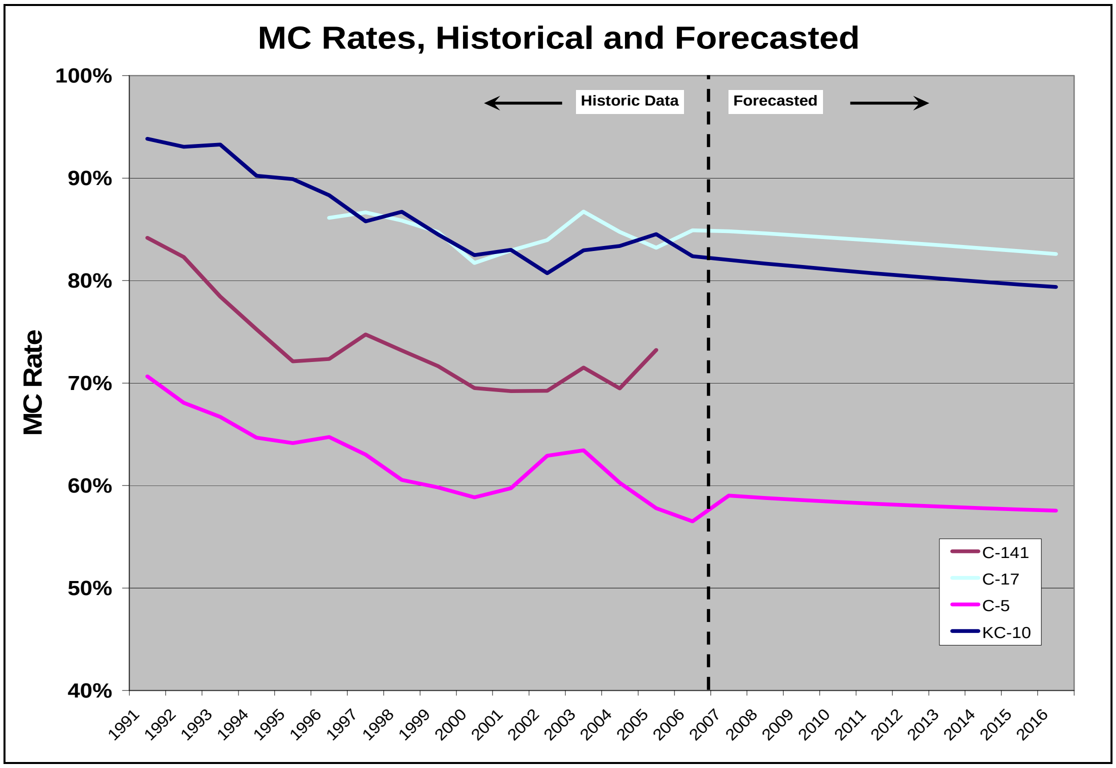

Figure 8: Historical and Forecasted Mission Capability Rates.

3.3.2 Forecast Results

The MAC Model's forecasting results indicate good news – the overall MAC is increasing in the outyears from 45 MTM/D currently to 49 MTM/D. Since the MAC Model forecasts the MC rates for all MDs to have declining trends, the increasing MAC can be attributed to the increasing C-17 TAI. This helps make the case that capability is a function of both MC rates and number of unit-possessed aircraft. While one factor (in this case, MC rates) is declining and another factor (in the case number of aircraft) is increasing at a higher rate, the overall outcome will be an increasing MAC trend.

The MAC Model allows for taking a look at a more idealized environment in military mobility operations, sort of a best case scenario. One can run different test cases of MC rates by accomplishing "what-if" drills to see how much improvement would be gained in the MAC, especially if the MDs were to operate at their established MC rate goals from FY07 onward (see Figure 9 for these goals).

As shown in Figure 10, the FY2016 fleetwide MAC would improve from 49.3 to 53.1 MTM/D, an increase of about 8%.

MD	MC Rate Type	MC Rate	MAC (MTM/D)
C-17	Goal	87.5%	18.48
	FY2016	82.6%	17.44
C-5	Goal	75.0%	11.09
	FY2016	57.6%	8.51
KC-10	Goal	85.0%	3.00
	FY2016	79.4%	2.80

Figure 9: Forecasted MC Rates & Goals vs. MAC.

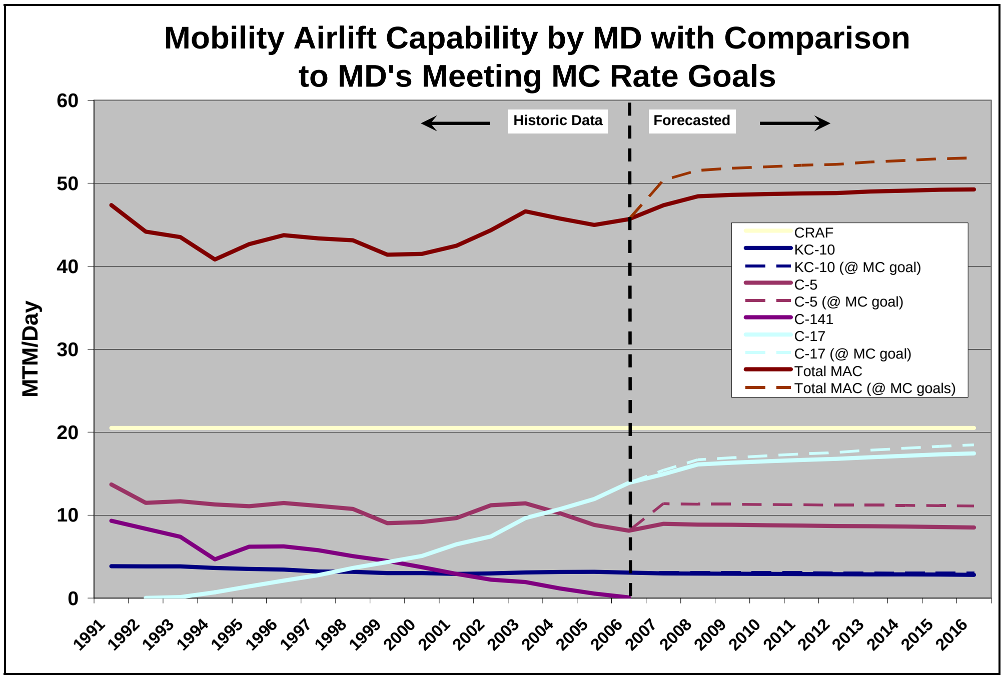

Figure 10: Historical and Forecasted Mobility Airlift Capability by Forecasted and Goal MC Rates.

As this model is fine tuned through improvements to its estimation capabilities for future MC rates (by including the affects of reliability improvement modifications, better statistical forecasting techniques, etc.) and from acquiring more accurate MAC per mission capable aircraft data (including at the MDS level for the C-5), a better sense can be attained for what is truly achievable in fleetwide MAC.

4.0 C-5 MAINTENANCE DRIVERS

A vital aspect to understanding the affects of reliability improvement modifications is to understand the adverse affects of unreliable components and aircraft maintenance (inspections, repairs, etc.) on a mobility aircraft's MC rates and subsequently on its MAC. This can be seen in the overall slow decline of the historical C-5 MAC trend. The historical C-5 MC rate trend is declining at a high pace, and conversely, it's not mission capable (NMC) rate is increasing. Since it has been shown that the MC rate (in addition to TAI) plays a large role in each MD's MAC, the remainder of this paper will focus on how drivers contribute to increasing NMC rates (and decreasing MC rates) for the C-5, the point being that any measures taken to improve MC rates will directly serve to improve its MAC and thus the overall capability of the USAF's mobility forces.

The discussion will start with an explanation of the relationship between MC and NMC rates with a breakdown of the submetrics within NMC rates. Then the high maintenance drivers will be presented to give the reader an understanding of the variety of reasons for why the C-5 is not meeting its MC rate goal of 75%.

4.1 NMC Rate Breakdown

The MC rate is defined as MC = 1 – NMC. NMC, a measurement of field-level scheduled and unscheduled maintenance and supply issues, is defined as NMC = NMCM + NMCS + NMCB. These NMC submetrics are defined as follows:

- NMCM = NMCMS + NMCMU + NMCMSA + NMCMUA
- NMCS = NMCS + NMCSA
- NMCB = NMCBS + NMCBU + NMCBSA + NMCBUA

Therefore, putting all the submetrics together:

- NMC = NMCMS + NMCMU + NMCMSA + NMCMUA + NMCS + NMCSA + NMCBS + NMCBU + NMCBSA + NMCBUA

Thus, it can be stated that:

- MC = ***f***(NMCMS, NMCMU, NMCMSA, NMCMUA, NMCS, NMCSA, NMCBS, NMCBU, NMCBSA, NMCBUA)

The NMC metric descriptions are as follows [16]:

- NMCMS: Not Mission Capable Maintenance Scheduled. The aircraft cannot do any assigned missions because of scheduled maintenance. The aircraft cannot fly (restricted from use).
- NMCMU: Not Mission Capable Maintenance Unscheduled. The aircraft cannot do any assigned missions because of unscheduled maintenance. The aircraft cannot fly (restricted from use).
- NMCMSA: Not Mission Capable Maintenance Scheduled Airworthy. The aircraft cannot do any assigned missions because of scheduled maintenance. The aircraft can fly (not restricted from use).
- NMCMUA: Not Mission Capable Maintenance Unscheduled Airworthy. The aircraft cannot do any assigned missions because of unscheduled maintenance. The aircraft can fly (not restricted from use).
- NMCS: Not Mission Capable Supply. The aircraft cannot do any assigned missions because of supply. The aircraft cannot fly (restricted from use).
- NMCSA: Not Mission Capable Supply Airworthy. The aircraft cannot do any assigned missions because of supply. The aircraft can fly (not restricted from use).
- NMCBS: Not Mission Capable Both Maintenance and Supply Scheduled. The aircraft cannot do any assigned missions because of supply and scheduled maintenance. The aircraft cannot fly (restricted from use).

- NMCBU: Not Mission Capable Both Maintenance and Supply Unscheduled. The aircraft cannot do any assigned missions because of supply and unscheduled maintenance. The aircraft cannot fly (restricted from use).
- NMCBSA: Not Mission Capable Both Maintenance and Supply Scheduled Airworthy. The aircraft cannot do any assigned missions because of supply and scheduled maintenance. The aircraft can fly (not restricted from use).
- NMCBUA: Not Mission Capable Both Maintenance and Supply Unscheduled Airworthy. The aircraft cannot do any assigned missions because of supply and unscheduled maintenance. The aircraft can fly (not restricted from use).

4.2 NMC Rate Maintenance Drivers

In this section, a summary of the MC and NMC rates will be presented over the analysis period of FY91-06 followed by the top NMC rate maintenance drivers according to 1) top NMC submetrics, 2) top two-digit work unit codes (WUC), and 3) a combination of submetrics and two-digit WUCs.

4.3 MC and NMC Rate Summary

Over the entire analysis period, the average C-5 MC rate was 62.8%, 12.2% below AMC’s goal of 75% [17], and equates to an NMC rate of 37.2%. The best MC rate occurred at the beginning of the analysis period (FY91) and was 70.6% while the worst MC rate occurred at the end (FY06) and was 56.4%. With a loss of 14.2% over the 15 years, this equates to losing almost an average of 1% per year.

4.4 Top Drivers by NMC Submetrics Rates

After reviewing the NMC and NMC submetric historical rates for the C-5 from FY91-06, the author determined that of the 10 NMC submetrics comprising the NMC rate, only five NMC submetrics accounted for between 98.6% and 99.9% of the entire NMC rate, depending on the year. Therefore, the remainder of this study involved only these top five NMC submetrics. Listed in order of contribution to the overall NMC metric, they are: NMCMU, NMCS, NMCBS, NMCBU, and NMCMS (see Figure 11). It appears that of the five, NMCMU, NMCS, and NMCBS are the largest contributors.

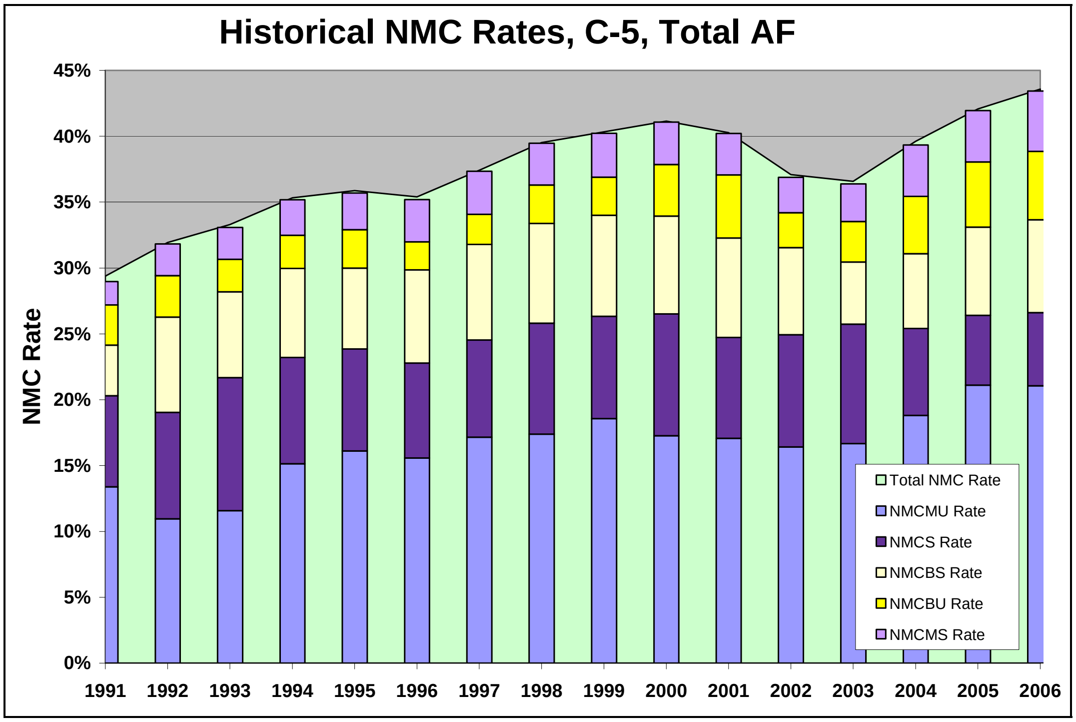

Figure 11: Historical NMC Rate with Top NMC Submetrics.

According to the NMC metrics and trend line chart in Figure 12, the NMCMU is not only the worst factor but its trend continues to get worse. The NMCS, historically second worst, is improving and being superseded by the NMCBS rate which looks to be trending flat. The best two of the five, NMCBU and NMCMS, are showing an increasing trend and may become a larger factor in the outyears by eventually overtaking NMCS and NMCBS if not corrected. Note: a similar method was used to compute the trend lines as discussed earlier in this paper and does not merit further discussion here.

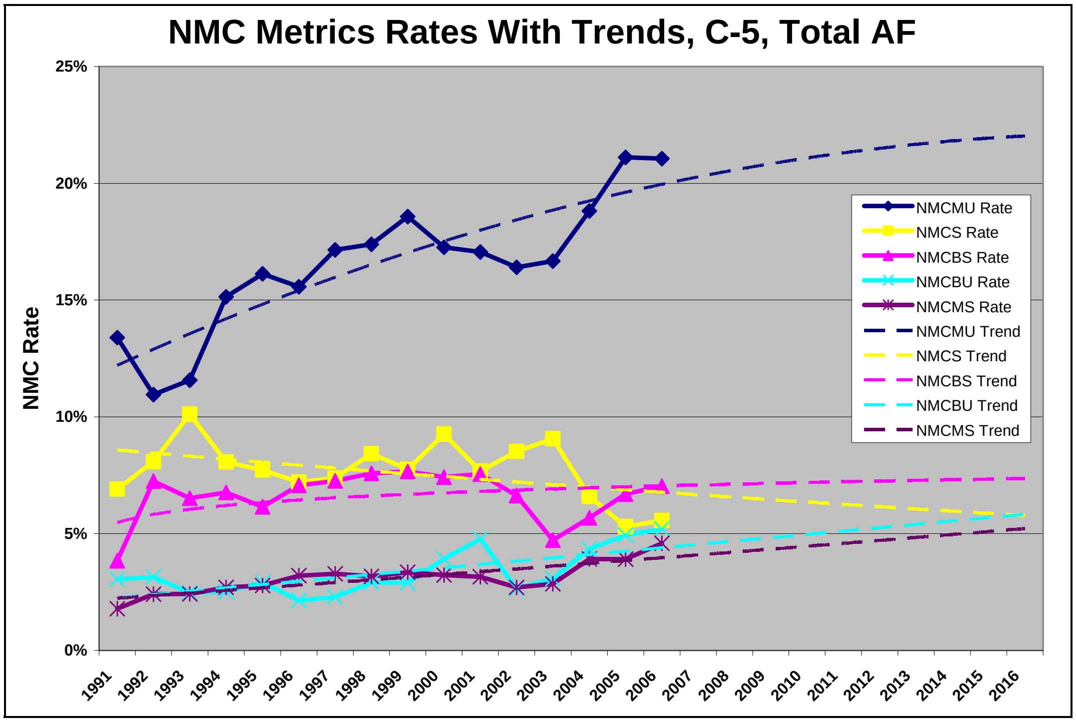

Figure 12: NMC Metrics Rates with Forecasted Trends.

Since NMCBU and NMCBS include combined maintenance and supply and the supply rate, NMCS, is improving, the author believes that NMCBU and NMCBS are mostly due to maintenance. Therefore, from the examination of the NMC submetrics, one can conclude that the NMC rate is being driven by scheduled and unscheduled maintenance.

4.5 Top Drivers by Two Digit WUCs

In reviewing the top NMC drivers according to two-digit WUCs from FY91-06, the bar chart in Figure 13 indicates scheduled inspections (WUC 03) followed by maintenance on engines (WUC 23), landing gear (WUC 13), airframe (WUC 11), and flight controls (WUC 14) were the worst drivers. However, the line chart in Figure 14 shows the downtime due to scheduled inspections has been decreasing steadily over the last 10 years while the maintenance on airframe, engines, landing gear and flight controls have been collectively worsening over the last few years.

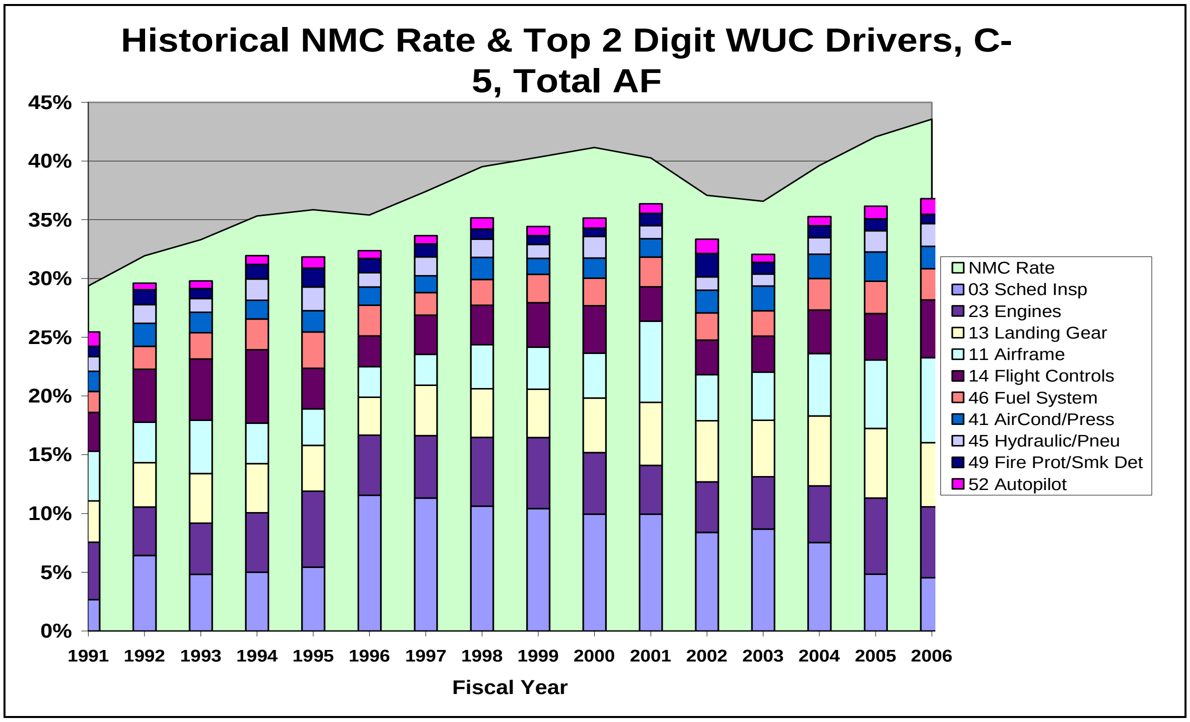

Figure 13: Historical NMC Rate and Top Two-Digit Work Unit Code NMC Drivers.

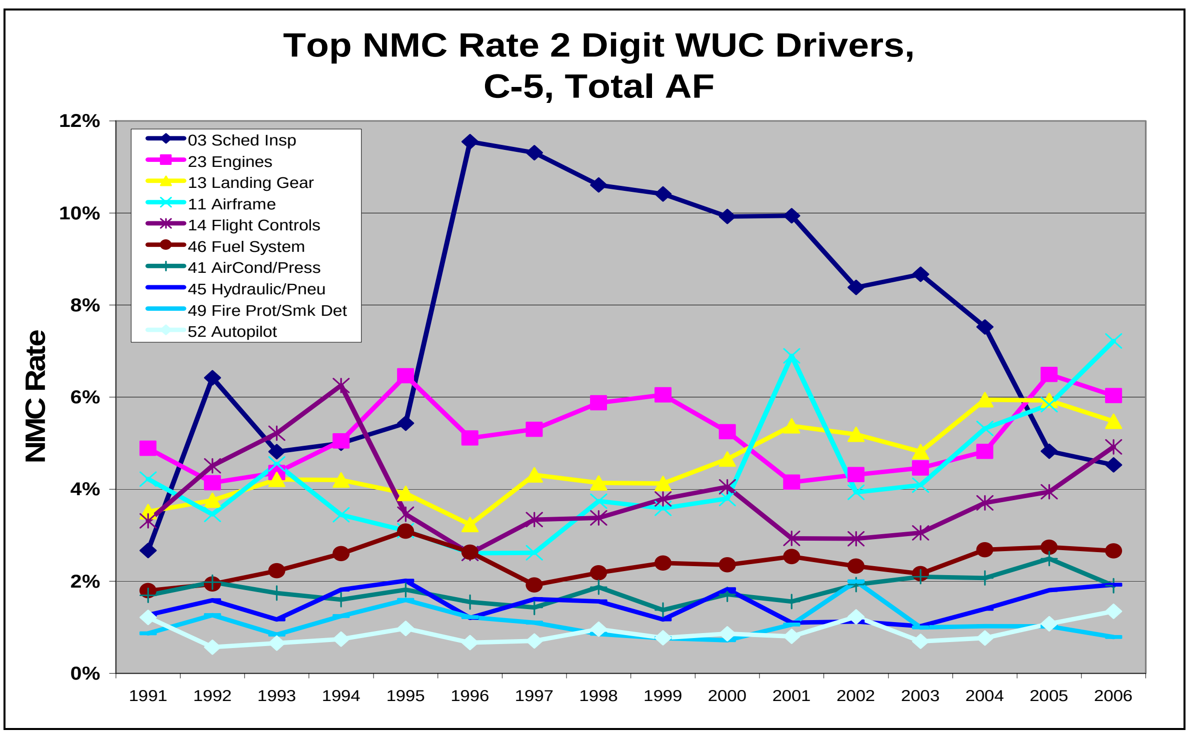

Figure 14: Top NMC Rate Two-Digit Work Unit Code Drivers.

An interesting and highly idealized "what-if" analysis was accomplished by adding the total of the minimum annual NMC rate contribution for each of the "Top 10" two-digit WUC drivers from FY 91-06 with the minimum annual NMC rate of the non-"Top 10" to get a best case scenario of all drivers. The outcome was that when all drivers behave in the best possible way (least impact to MC rate), mathematically, the NMC rate = 23.1%, resulting in an MC rate of 76.9%. So, with all things considered, meeting the MC rate goal of 75% is "possible." However, as can be seen in Figure 15, the minimum contribution to the overall NMC rate for the top 10 drivers did not fall in the same year or even the same short-term intervals thus leading to the more realistic conclusion that meeting the MC rate goal is most likely not achievable without significant changes to the aircraft and/or maintenance plan. (See assumption #3 above for discussion of planned C-5 upgrades.)

Top 10 NMC Drivers	Min NMC Rate	FY of Min
03 Sched Insp	2.7%	FY91
23 Engines	4.1%	FY92
13 Landing Gear	3.2%	FY96
11 Airframe	2.6%	FY96, 97
14 Flight Controls	2.6%	FY96
46 Fuel System	1.8%	FY91
41 AirCond/Press	1.4%	FY97, 99
45 Hydraulic/Pneu	1.0%	FY03
49 Fire Prot/Smk Det	0.7%	FY00
52 Autopilot	0.6%	FY92
Sum of Top 10	20.7%	
Non-Top 10 Total	2.3%	FY92
Best NMC Rate =	**23.1%**	
Best MC Rate =	**76.9%**	

Figure 15: Idealized NMC and MC Rates.

4.6 Top Drivers by Combination of NMC Submetrics Rates and Two Digit WUCs

Data from a combined perspective of NMC submetric rates and two digit WUCs was plotted in Figures 16a-e. As seen in Figure 16a, it appears that the supply submetric, NMCS, had significant rates in the past primarily due to flight controls (WUC 14) from FY92-94 and scheduled inspections (WUC 03) from FY96-03 but is improving due to the currently low and stable influences of all WUCs. For the unscheduled submetrics (NMCMU and NMCBU), as seen in Figures 16b and c, the top WUCs are engines (WUC 23), landing gear (WUC 13), airframe (WUC 11), and flight controls (WUC 14). For the scheduled submetrics (NMCBS and NMCMS), as seen in Figures 16d and e, the top metric was inspections (WUC 03) and to a lesser degree, airframe (WUC 11) (and to an even lesser degree for NMCMS, engines, WUC 23).

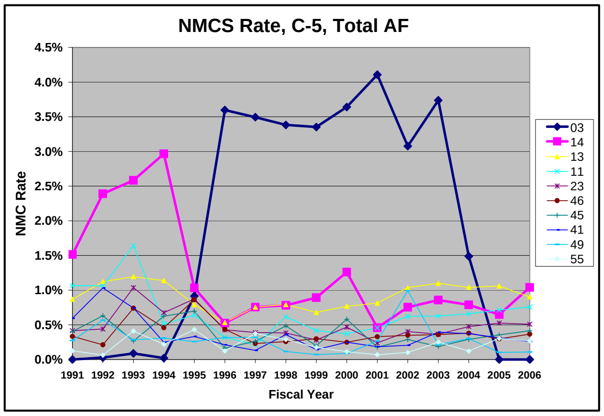

Figure 16a: NMCS Rate.

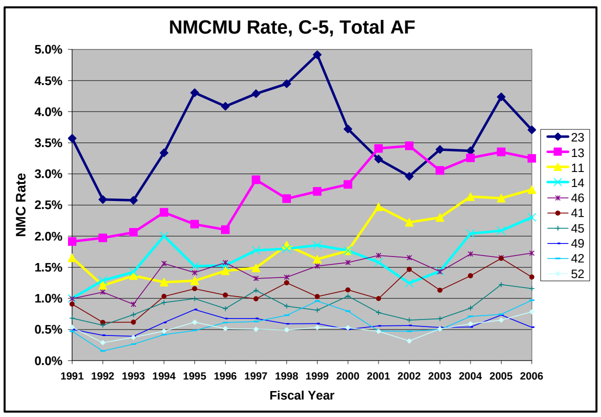

Figure 16b: NMC Unscheduled Maintenance Rate.

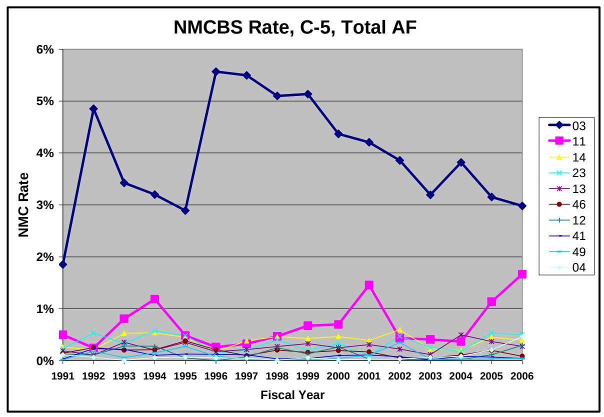

Figure 16c: NMC Scheduled Both Rate.

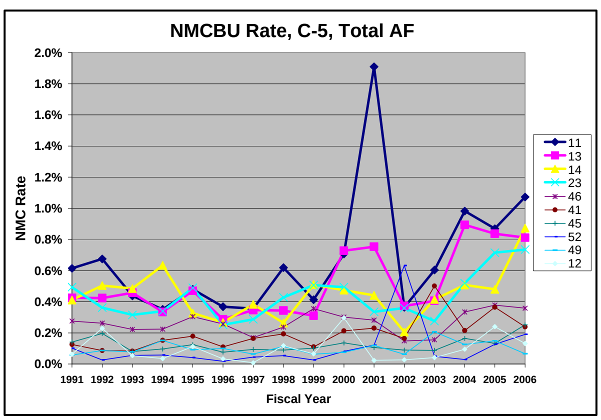

Figure 16d: NMC Unscheduled Both Rate.

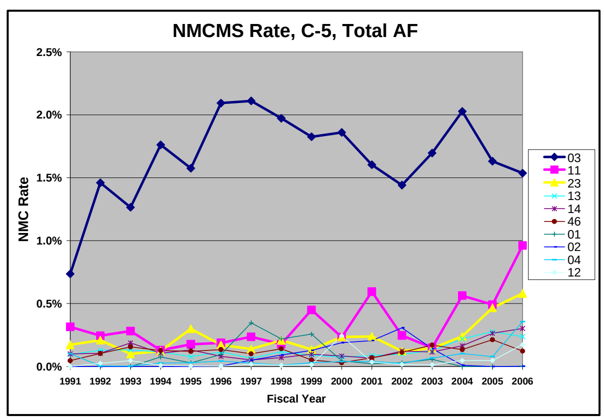

Figure 16e: NMC Scheduled Maintenance Rate.

In summary, when looking at the combination of NMC submetrics with WUCs, the highest drivers are unscheduled maintenance on engines, landing gear, airframe, and flight controls and scheduled maintenance for inspections, airframe, and engines.

5.0 INFLUENCES ON MOBILITY AIRLIFT CAPABILITY

As stated in the MAC Model Methodology subsection above, the MAC is essentially the MAC per MC aircraft multiplied by the number of MC aircraft. To determine the number of MC aircraft, one needs to multiply the number of annual possessed aircraft by that year’s average MC rate. But what are all the factors that can impact MAC and its elements? In addition to examining the specific high maintenance drivers of sub-standard MC rates and lower MAC levels, a discussion on general causes is worthwhile.

5.1 Mobility Airlift Capability per Mission Capable Aircraft Influences

The MAC per MC aircraft is affected by a variety of aircraft parameters, for instance (in no particular order and not a complete list):

1) Cargo capacity of the aircraft. This is a fixed characteristic; the only way to change it is through structural modification or internal cargo area reconfiguration.
2) Mission throughput. This has to do with the offload/reload speed and efficiency and is related to cargo door sizes and locations.
3) Engine thrust. This affects the allowable cargo load.
4) Flight/load restrictions due to aging issues. This affects allowable cargo load.
5) Technological obsolescence. This results in the lack of an ability to perform the mission (mission effectiveness) in the current environment. Examples include a) congested airspace challenges – communication, navigation, surveillance/air traffic management (CNS/ATM) compliance (non-CNS/ATM-compliant aircraft will be unable to fly without special approval in European airspace or the oceanic track systems), and b) flying challenges – all-weather flying, traffic alert and collision avoidance, terrain awareness and warning, global positioning system (GPS), and autopilot/flight augmentation.

5.2 Mission Capability Rate Influences

The MC rate is related to a variety of aircraft maintenance parameters, for instance (in no particular order and not a complete list):

1) Troubleshooting and fault isolation time, retest OK (RTOK).
2) Quality of maintenance technical orders.
3) Depot-level reparable (DLR) funding.
4) Supply system efficiency (supply issue effectiveness rate, stockage effectiveness rate).
5) Break rate, fix rate, total repair cycle time, customer wait time.
6) Mean time between failure (MTBF), mean time to repair (MTTR), mean time between maintenance (MTBM).
7) MICAP hours, MICAP incidents, cannibalizations.

8) "Fly-to-fail" sustainment strategy vs. "time change" strategy of mission-essential parts (to be changed during scheduled maintenance).
9) Maintenance manning level (assigned personnel vs. authorized personnel).
10) Maintenance personnel training.
11) OPS tempo, deployments, scheduled exercises.
12) Number and type of time compliance technical orders (TCTOs).
13) Maintenance squadron dock flow.
14) Aerospace ground equipment (AGE) maintenance.
15) Aircraft inspection intervals, complexity, equipment availability, comprehensiveness.

5.3 Total Mobility Airlift Capability Influences

The MAC is impacted by, in addition to the influences for the MAC per aircraft and the MC rate, the number of aircraft as follows:

- Total aircraft inventory.
- Number of unit-possessed aircraft. A significant factor here is the number of depot-possessed aircraft at any given time which takes away aircraft from the unit. Aircraft are considered depot possessed when they undergo extensive structural life extension program (SLEP) and modernization (planned changes to a weapon system to provide mission, reliability, maintainability, and/or safety required improvements) modifications, programmed depot maintenance (PDM), unscheduled depot level maintenance (UDLM), maintenance accomplished by depot field teams (DFT), etc.

6.0 CONCLUSIONS

This paper presented a model that connected MC rates to the flying units' warfighting capability using data from the USAF Mobility Force's aircraft (C-5, C-17, C-141, and KC-10).

In examining the MAC Model's forecasting results, the good news is that it appears the overall MAC is increasing, from 45 MTM/D currently to 49 MTM/D in the outyears. Since the MAC Model predicts the MC rates for all the MDs to have declining trends, the increasing MAC can be attributed to the rising C-17 TAI. This helps make the case that capability is a function of both MC rates and number of unit-possessed aircraft. While one factor (in this case, MC rates) may be declining and another factor (in the case number of aircraft) is increasing at a higher rate, the overall outcome will be an increasing MAC trend. However, unless there is a boost in TAI (as currently with the C-17) or a growth in unit-possessed aircraft (less depot time), a decrease in MC rate will result in a reduction in MAC.

To illustrate this specifically, the maintenance data for the C-5 was analyzed in detail. The results indicate the highest NMC drivers limiting improvements to MC rates are unscheduled maintenance on engines, landing gear, airframe, and flight controls and scheduled maintenance for inspections, airframe, and engines.

To illustrate this in more general terms, the influences on MAC per aircraft, total MAC, and MC rate were considered. The MAC per aircraft depends on a variety of aircraft parameters including cargo capacity, mission throughput, engine thrust, flight/load restrictions, technological obsolescence, etc. The MC rate is affected by specific drivers and a variety of maintenance and logistics parameters including maintenance quality, equipment, technology, processes, policy, supply, ops tempo, personnel, facilities, etc. The total MAC varies with, in addition to the MAC per aircraft and the MC rate, the TAI and the number of unit-possessed aircraft.

Top AF leaders are concerned about the impact aging of the USAF aircraft inventory has on operational readiness and mission capability. This presents the AF with a significant dilemma: Aging is an issue that will not easily be fixed and new aircraft will not be delivered fast enough to divest the USAF of these aging airplanes in the short term. To ensure these aircraft will be in flyable condition until the last aircraft are replaced, sustainment must be a priority, and to make this prioritization a reality and justify improved funding, the AF must communicate the importance of sustainment better. Success in this endeavor requires the AF to effectively equate sustainment to warfighting capability.

7.0 RECOMMENDATIONS

To improve the confidence in the prediction results, future model iterations should involve the following:

1) Obtain the MAC by MDS.
2) Assume the MAC per MC aircraft for each weapon system has not been constant through the years. Determine how it has changed and will change as a function of modifications (that have been completed, are currently being completed, and are being planned). The results should be by MDS.
3) Determine realistic improvements to MC rates the AF expects for modifications currently being completed and planned, especially for the C-5A, C-5B, and C-5C. The results should be by MDS.
4) Further investigate the MC rate forecasting methodologies presented in paragraphs 1 and 3 and the maintenance simulation methodology in paragraph 2 of the Background section. Incorporate the best approach(es) into the MAC Model.
5) Add in sophisticated statistical methodologies to forecast the number of possessed aircraft by MDS.
6) Develop a methodology for determining average annual TAI by FY for each MDS.

8.0 METRICS DATABASES

In addition to the references below, the following sources were used to collect AF maintenance and inventory data:

1) Multi-Echelon Resource and Logistics Information Network (MERLIN). MERLIN is a web-enabled, integrated reporting and analysis software tool originally developed for Headquarters, U.S. Air Force, Installations and Logistics (HQ USAF/ILMY). This tool provides the capability to generate ad hoc performance measurement reports and access historical data. It provides comparative analysis of performance, funding, and aircraft inventory metrics which can be viewed across multiple weapon systems, major commands, and time periods.
2) Air Force Knowledge Services (AFKS). AFKS consolidates a multitude of Air Force maintenance, supply, inventory, and other aircraft data from a variety of legacy databases. This interface provides the Air Force with a single portal to more accurate, real-time information to assess aircraft readiness, monitor aircraft configuration and status, analyze aircraft histories, and provide awareness of specific aircraft availability.

9.0 REFERENCES

[1] Air Force Print News, "Air Force Focused on Three Priorities," 12 Oct 06.

[2] Air Force Association's 2005 Air and Space Conference and Technology Exposition, 12 Sep 05, Washington DC.

[3] Air Force Print News, "Air Force Focused on Three Priorities," 12 Oct 06.

[4] 2002 Annual Defense Report, Chapter 5, Sizing and Selectively Modernizing Forces for an Era of Uncertainty.

[5] Proceedings of the 2000 Winter Simulation Conference, "A Simulation Approach to Estimating Aircraft Mission Capable Rates for the United States Air Force," Balaban, Brigantic, Wright, and Papatyi.

[6] 15th European Simulation Multiconference, 2001, Raivo, Kuumola, Mattila, Virtanen, and Hämäläinen.

[7] 2001 Logistics Challenges, Volume XXV, Number 3, "Forecasting Readiness," Oliver, Johnson, White, Arostegui, Fall 2001.

[8] US General Accounting Office report, "Military Readiness: Updated Readiness Status of U.S. Air Transport Capability," GAO-01-495R, 16 Mar 01.

[9] US General Accounting Office report, "Military Readiness: Air Transport Capability Falls Short of Requirement," GAO/NSIAD-00-135, Jun 00.

[10] 2002 Annual Defense Report, Chapter 5, Sizing and Selectively Modernizing Forces for an Era of Uncertainty.

[11] US General Accounting Office report, "Military Readiness: Updated Readiness Status of U.S. Air Transport Capability," GAO-01-495R, 16 Mar 01.

[12] 2004 Annual Defense Report, Table 1-6, Mobility Forces.

[13] United States Air Force Statistical Digest, FY2005, Table E-6.

[14] DoD Quadrennial Defense Review Report, 6 Feb 06.

[15] Ibid.

[16] Air Force Instruction (AFI) 21-103, Equipment Inventory, Status And Utilization Reporting, 14 Dec 05.

[17] Metrics Handbook for Mobility Air Force, 2nd Edition, Dec 03.